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ORIGINAL PAPER

Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh

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Abstract: A study was conducted at two-biodiversity conservation areas of Northeastern Bangladesh (a part of Sylhet Forest Division) to assess the species composition, diversity and density of natural regeneration of tree species both indigenous and exotic species. Data were collected by stratified random quadrate method during January 2010 to July 2010. Totally 200 circular plots of 2 m×2 m in size had 5 different habitat types of plants namely; forest, roadside, homestead (surrounding forest dwellers house), fallow land and others (canals, streams and tea gardens side), which included a total of 55 regenerating species belonging to 28 families. Meliaceae is the dominant family and shows the highest family importance value (26.3), having six species, followed by Moraceae (24.24). Among the five habitat types, forest (43 species) possess the highest number of species, followed by roadside (23 species). Total 15 exotic species among 9 families and 40 indigenous species with 24 families were recorded. For exotic species, *Tectona grandis* possess the highest relative density (11.7%) and relative frequency (10.5%); *Senna siamea* had highest relative abundance (7.83%). In case of indigenous species, *Chickrassia tabularis* possess the highest relative density (4.23%) and relative frequency (4%); *Dipterocarpus turbinatus* had the highest relative abundance (3.92%). *Tectona grandis* (29.66) and *Chickrassia tabularis* (10.8) had the highest IVI for exotic and indigenous species respectively. Different diversity indices such as Shanon-Winner diversity index, species diversity index, species richness index, species evenness index, Simpson index and species dominance index, etc. were applied to quantify definite diversity. The regeneration of species associated with low levels of disturbance was in the exotic species. Study suggests that proper protection from human disturbances and scientific management of natural regeneration of two-study forests may lead a rich biodiversity site in the country.

Keywords: biodiversity; exotic species; family importance value; indigenous species; quantitative characters

Introduction

The nature of forest communities depends on the ecological characteristics in sites, species diversity and regeneration status of species. Micro-environmental factors vary with seasonal changes, which affect the trees growth stage i.e. seedling, sapling, coppice, and young trees that maintain the population structure (Khumbongmayun et al. 2006). Natural regeneration is essential for preservation and maintenance of biodiversity. Depending on management objectives, it is important to maintain the process of forest renewal by appropriate natural and artificial regeneration. The clear felling accelerates loss of seedlings and saplings as well as disturbs the natural condition of the natural forests and hence the ecosystem (Haque et al. 1988). Knowledge about the pattern of natural regeneration is important to answer the basic question of forest management (Hossain et al. 1999).

Bangladesh vegetation is a part of the Indo-Myanmar region, which is one of the ten global hot spot areas for biodiversity, with 7 000 endemic plant species (Mittermeier et al. 1998) and rich biological diversity, due to its unique geo-physical location (Hossain 2001; Barua et al. 2001; Chowdhury 2001; Nishat et al. 2002). Muhammed et al. (2008a) mentioned that forests in Bangladesh are deteriorating at an alarming rate due to various socio-economic threats, biotic pressures and competing land uses. The high degree of dependency that many people have on the forests for their livelihoods has resulted in depletion of natural resources and degradation of forest ecosystems countrywide (Muhammed et al. 2008b). A few researchers (Hossain 2005; Khan et al. 2007; Mukul 2007; Mukul et al. 2008; Chowdhury et al. 2010), estimated that the total amount of forest cover of Bangladesh is nearly about 2.53×10^6 ha, representing approximately 17.5% of total surface area of the country. According to estimate by FAO (2007), the total growing stock of Bangladesh's forests is 30×10^6

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m^3 and the total biomass 63×10^6 tons. However, in 2008, the area of total forest land of Bangladesh from Bangladesh Forest Department is 2.52×10^6 ha (BFD 2008). Rahman et al. (2000) and Hossain (2001) found that the depletion of native species was also accelerating at an alarming rate through the rapid loss and degradation of forests in Bangladesh.

For conservation and management of tropical plant diversity across the biodiversity conservation areas, the information on plant diversity is considered as necessary because of its potential usefulness and implications (Kadavul et al. 1999). Many researchers (Pritts et al. 1983; Saxena et al. 1984; Khan et al. 1987; Ashton and Hall 1992; Cao et al. 1996; Gunatilleke et al. 2001; Uma 2001) have carried out various studies on population structure and regeneration status but these studies were limited in different forest ecosystems in Bangladesh. Thus, the aim of this study was to assess the natural regeneration composition, status and diversity of tree species in two biodiversity conservation areas namely Khadimnagar National Park and Tilagaor Eco-Park of Northeastern Bangladesh. In both the study sites, the ground is covered with herbs, ferns, bamboo, and rattan. Regeneration is occurring mainly through dispersed seeds from the forest.

Materials and methods

Study sites

The study was conducted in and around biodiversity conservation areas namely, Khadimnagar National Park (KNP) and Tilagaor Eco-Park (TGEP). These areas were selected purposively considering their unique geo-physical features in biological diversity. KNP (N 24º56'–24º58' and E 91º55'–91º59') and TGEP (N 23º55'–25º14' and E 90º55'–92º31') are located at North Sylhet Range-1 in Sylhet Forest Division under tropical evergreen and semi-evergreen bio-geographic zone. KNP was declared as National Park in 2006, which was formerly known as Khadimnagar Reserve Forest. Total area of KNP is 679 ha, surrounded by three tea gardens, and submerged with several watersheds locally known as "*chara*". TGEP was declared as Eco-Park in 2006 with a total area of 45.35 ha. The hills of these areas are generally low and gently sloping. Soil ranges from clay loams to pale brown (acidic) clay loams on the hills. The tropical monsoon climate prevails in the area with an average maximum temperature of 30.7 °C and average minimum temperature of 18.9°C. The average annual rainfall is 3931mm, most of which falls between June-September (BBS/UNDP 2005). The forest areas are undulating with slopes and hillocks, locally called *tilla*. The study forests are semi-deciduous tropical forest type.

Methods

The present study was carried out from January 2010 to July, 2010. A stratified random quadrate method was used to determine the regeneration status of the tree species of KNP and TGEP of Northeastern region, Bangladesh. Sample plots in the study areas were selected from five different habitats namely; forest, roadside, homestead (surrounding forest dwellers house), fallow land and others (canals, streams and tea gardens side). Total 200 sample plots (100 from KNP and 100 from TGEP) of 2 m×2 m in size. The characteristics of all seedlings/saplings and coppices of both indigenous and exotic species were recorded. Species density, frequency and abundance were calculated by the methods of Shukla and Chandal (2000). The relative density, relative frequency and relative abundance were calculated by the methods of Misra (1968). Importance Value Index (IVI) were calculated by the methods of Shukla and Chandal (2000). The collected species were identified (Prain 1903; Brandis 1906; Heining 1925; Das et al. 2001; Dey 2006). During the present study, eight diversity and richness indices were analyzed to get a clear picture of regeneration diversity tree species in the study areas:

$$S_{DI}=S/N \quad (1)$$

where, S_{DI} is the species diversity index (Odum 1971); S the total number of species; N the total number of individuals of all the species.

$$R= (S\text{-}1) / \mathrm{Ln}\ (N) \quad (2)$$

where, R is the species richness index (Margalef 1958); n is the number of individuals of each species.

$$H = -\sum P_i \mathrm{Ln} P_i \quad (3)$$

where, H is the Shannon-Winner diversity index (Michael 1990), and P_i is the number of individuals of one species/Total number of individuals in the samples.

$$H_{max}=\mathrm{Ln}\ (S) \quad (4)$$

where, H_{max} is Shannon's maximum diversity index (Kent et al. 1992), S is the total number of species.

$$E_H=H/H_{max} \quad (5)$$

where, E_H is Shannon's equitability index (Kent et al. 1992); H the Shannon-Winner diversity index; H_{max} the Shannon's maximum diversity index.

$$E= H/\mathrm{Log}\ (S) \quad (6)$$

where is E is the species evenness index (Pielou 1966), H the Shannon-Winner diversity index, and S the total number of species.

$$D=\sum P_i^2 \quad (7)$$

where, D is the Simpson index (Magurran 1988), P_i is the Number of individuals of one species/Total number of individuals in the samples. As biodiversity increases, the Simpson index decreases. Therefore, it is worthy to get a clear picture of species dominance.

$$D'=1\text{-}D \quad (8)$$

where, D' is dominance of Simpson index.

$$F_d\,(\%) = N_f/T_i \times 100 \quad (9)$$

where, F_d is the family relative density (%) (Mori et al. 1983), N_f is No. of individuals in a family; T_i is the total no. of individuals.

$$'F_r\,(\%) = N_s/T_s \times 100 \quad (10)$$

where, F_r is the family relative diversity (%); N_s is No. of species in a family; T_s is the total number of species.

Results

Natural regeneration status of species in KNP and TGEP

In the two study sites, about 3 818 individuals were found in 800 m^2-sampled areas (Table 1). About 55 species under 28 families with 43 genera were encountered in the two sites, with KNP's forest having the highest number of species (43 species), and TGEP forest (31 species). In case of regeneration mode, almost 95% species were found to regenerate through seedling, sapling, and rest 5% of the species was through coppicing. Twenty-nine species occurred in KNP while rests were found in two sites. About 72% families is represented by only one species, while 7% families is represented by two and three species and 14% families comprises more than three species in the two study sites. Families with high numbers of different species are Meliaceae (6 species), Moraceae (6 species), Mimosaceae, Myrtaceae, Combretaceae and Euphorbiaceae every (3 species), Rutaceae, Caesalpiniaceae, Verbenaceae both (2 species in each) and rest of the families comprise one species. Besides, three unidentified species also were found in two study sites. Moreover, there were 15 exotic species in the study sites among 9 families (1 unidentified species with family) where 40 indigenous species under 24 families (2 unidentified species with families) recorded. In case of exotic species, 55.56% family comprises only one species, 33.33% family with two species and 11.11% family with three species. In case of indigenous species, 79.17% families comprise only 1 species, 4.17% family with two species, 8.33% family with more than three species.

Family importance value (FIV) index of recorded species is also given in Table 1. The individuals number of species and FIV were the highest for the recorded family of Meliaceae (individuals 550, FIV 26.3), followed by Moraceae (individuals 472, FIV 24.24), Combretaceae (individuals 241, FIV 12.3), Euphorbiaceae (individuals 231, FIV 12), Mimosaceae (individuals 208, FIV 11.4), Cassuarinaceae (individuals 29, FIV 2.7) and lowest for Santalaceae (individuals 19, FIV 2.43). Results also revealed that regeneration frequency of both indigenous and exotic species was varied in five different habitats (forest, fallow land, homestead, roadside, and others) (Table 2). Among these five habitats, diversity of indigenous species was highest in forest (36 species), followed by roadside (11 species), fallow land (7 species), others (5 species) and homestead (4 species) while it was different for exotic species. Diversity of exotic species was highest in roadside (12 species), followed by fallow land (9 species), forest (7 species), homestead (3 species) and others (2 species). Results of this study also indicated that total fifty-five species in forest had the highest number of species (43 species), followed by roadside (23 species), fallow-land (16 species), others and homestead (7 species in each). The composition and richness of understory plant species in different habitats are presumably due to their different responses to abiotic factors such as differential light levels, nutrient availability, water availability, wind, and temperature (Laska 1997; Svenning 2000; Siebert 2002).

Quantitative characters of natural regenerated species

The total seedling/sapling/coppice of exotic and indigenous species were estimated 1238 and 2580 respectivey from two study sites (Table 3, 4). For exotic species, the highest density was recorded for *Tectona grandis* L.f. from both natural regeneration and coppices (0.62), followed by *Xylia dolabriformis* Benth. (K. kerrii) (0.45), and *Albizia procera* (L.) Benth. (0.43). But in case of indigenous species, the highest density was found for *Chickrassia tabularis* Juss. (0.59), followed by *Artocarpus chaplasha* Roxb. (0.58) and *Terminalia arjuna* Bedd. (0.57), and lowest for *Santalum album* L. (0.1).

Exotic species had the highest frequency (34.5%) of *T. grandis*, followed by *X. dolabriformis* (28.5%), and *A. procera* (26.5%). On the other hand, the highest frequency of indigenous species was calculated for *C. tabularis* (32.5%), *A. chaplasha* and *T. arjuna* both contains (32%).

Some major exotic species with highest values of abundance were for *Senna siamea* Lam. (1.88), *T. grandis* (1.78) and Unidentified-1 (1.77). But indigenous species with highest abundance are for *Dipterocarpus turbinatus* Gaertn. (2.7), *Aquilaria agallocha* Lamk. (2.5) *Zanthoxylum rhetsa* (Roxb.) DC. (2.18), *Bombax ceiba* Linn. (2.1) and *Hydnocarpus kurzii* King (2.08).

The relative density of *T. grandis* was the highest (11.7%), followed by *X. dolabriformis* (8.47%), and *A. procera* (8.09%) for exotic species. Furthermore, in indigenous species the relative density for *C. tabularis* (4.23%) was the highest, followed by *A. chaplasha* (4.16%) while the lowest for *S. album* (0.69%) respectively.

The relative frequency of *T. grandis* in exotic species was the highest (10.5%), followed by *X. dolabriformis* (8.69%), *Swietenia mahagoni* (Linn.) Jacq. (8.23%), *A. procera* (8.08%) and lowest for Unidentified-1 (3.35%) respectively. In indigenous species, the relative frequency of *C. tabularis* were highest (4%), followed by *A. chaplasha* and *T. arjuna* together (3.93%) in that order.

However, the relative abundance of *S. siamea* was the highest value (7.83%), followed by *T. grandis* (7.44%), Unidentified- 1 (7.39%) in that order. In case of indigenous species, *D. turbinatus* (3.92%) has highest relative abundance, followed by *A. agallocha* (3.64%) *Z. rhetsa* (3.16%) and *B. ceiba* (3.05%) respectively.

T. grandis had the highest IVI value (29.66), followed by *X. dolabriformis* (23.67), *A. procera* (22.86) and *Lagerstroemia speciosa* (L.) Pers. (22.66) respectively for exotic species. *C. tabularis* has the highest IVI value (10.8) in indigenous species, followed by *A. chaplasha* (10.7), *T. arjuna* (10.6), *Michelia champaca* L. (10.1), *Syzygium grande* (Wt.) Wall. and *Apha-*

namixis polystachya (Wall.) R. N. Park. (9.85 each).

Table 1. Species composition, species classification, mode of availability of regeneration, family relative density (FRD), family relative diversity (FRDI), and family importance value (FIV) index of recorded species in KNP and TGEP of Northeastern Bangladesh

Family	Scientific name	Local name	I/E*	Mode of available regeneration*	Number of individuals**	FRD (%)	FRDI (%) **	FIV
1. Anacardiaceae	1. *Mangifera indica* Linn.	Aam	I	Se, Sa	51	1.37	1.92	3.3
2. Apocynaceae	2. *Alstonia scholaris* R.Br.	Chatim	I	Se, Sa	64	1.72	1.92	3.65
3. Bixaceae	3. *Bixa orellana* Linn.	Lotkon	I	Se, Sa	43	1.16	1.92	3.08
4. Bombacaceae	4. *Bombax ceiba* Linn.	Shimul	I	Se, Sa	88	2.37	1.92	4.29
5. Caesalpiniaceae	5. *Cassia fistula* Linn.	Sonalu	E	Se, Sa	49	3.39	3.85	7.24
	6. *Senna siamea* Lam.	Minjiri	E	Se, Sa	77			
6.Caesalpinoideae	7. *Bauhinia acuminata* Linn.	Kanchon	I	Se, Sa	54	1.45	1.92	3.38
7.Cassuarinaceae	8. *Casuarina equisetifolia* Linn.	Jhau	I	Se, Sa	29	0.78	1.92	2.7
8. Combretaceae	9. *Terminalia arjuna* W & A.	Arjun	I	Se, Sa	113	6.49	5.77	12.26
	10. *Terminalia chebula* (Gaerth.)Retz.	Horitoki	I	Se, Sa	66			
	11. *Terminalia bellirica* (Gaertn) Roxb.	Bahera	I	Se, Sa	62			
9.Dipterocarpaceae	12. *Dipterocarpus turbinatus* Gaertn.	Garjon	I	Se, Sa	89	2.4	1.92	4.32
10. Euphorbiaceae	13. *Baccaurea ramiflora* Lour.	Bhubi	I	Se, Sa	94	6.22	5.77	11.99
	14. *Phyllanthus emblica* Linn.	Amoloki	I	Se, Sa	73			
	15. *Trewia polycarpa* Benth.	Chagalledi	I	Se, Sa	64			
11. Fabaceae	16. *Dalbergia sissoo* Roxb.	Sissoo	E	Naturalized	79	2.13	1.92	4.05
12. Flocourtiaceae	17. *Hydnocarpus kurzii* (King) Warb.	Chalmugra	I	Se, Sa	75	2.02	1.92	3.94
13. Guttiferae	18. *Mesua nagassarium* (Burn. f.) Kost.	Nageswar	E	Se, Sa	58	1.56	1.92	3.48
14. Lauraceae	19. *Litsea monopetala* (Roxb.) Pers.	Menda	I	Se, Sa	63	1.7	1.92	3.62
15. Leguminosae	20. *Xylia dolabriformis* Benth. (K. kerrii)	Lohakat	E	Se, Sa	89	4.26	3.85	8.11
	21. *Tamarindus indica* Linn.	Tatul	I	Se, Sa	69			
16. Lythraceae	22. *Lagerstroemia speciosa* (Linn.) Pers.	Jarul	E	Se, Sa	84	2.26	1.92	4.18
17. Magnoliaceae	23. *Michelia champaca* Linn.	Champa	I	Se, Sa	106	2.86	1.92	4.78
18. Meliaceae	24. *Aphanamixis polystachya* (Wall.) R. N. Park.	Pitraj	I	Se, Sa	102	14.8	11.5	26.3
	25. *Azadirachta indica* A. Juss.	Neem	I	Se, Sa	84			
	26. *Chickrassia tabularis* Juss.	Chickrasi	I	Se, Sa	117			
	27. *Swietenia mahagoni* (Linn.) Jacq.	Mahagoni	E	Se, Sa	83			
	28. *Toona ciliata* J.Roem.	Kuma	I	Se, Sa	91			
	29. *Melia sempervirens* (Linn.) All.	Bokhain	I	Se, Sa	73			
19. Mimosaceae	30. *Albizia lebbeck* (Linn.) Benth.	Sirish	E	Se, Sa	68	5.6	5.77	11.37
	31. *Albizia procera* Benth.	Malakanna	E	Se, Sa	85			
	32. *Acacia auriculiformis* Willd.	Akashmoni	E	Se, Sa	55			
20. Moraceae	33. *Artocarpus chaplasha* Roxb.	Chapalish	I	Se, Sa	115	12.7	11.5	24.24
	34. *Artocarpus heterophyllus* Lamk.	Kanthal	I	Se, Sa	55			
	35. *Artocarpus lacucha* Buch-Ham.	Dewa	I	Se, Sa	43			
	36. *Ficus roxburghii* Wall	Dumur	I	Se, Sa	99			
	37. *Ficus benghalensis* Linn.var.krishnae	Bot	I	Se, Sa	67			
	38. *Ficus racemosa* Linn.	Joggodumur	I	Se, Sa	93			
21. Myrtaceae	39. *Syzygium grande* (Roxb.) DC.	Dhakijam	I	Se, Sa	101	5.39	5.77	11.16
	40. *Eucalyptus camaldulensis* Dehn.	Eucalyptus	E	Coppice	55			
	41. *Eucalyptus grandis* Hill & ex Maiden.	Eucalyptus	E	Coppice	44			
22. Palmae	42. *Borassus flabellifer* Linn.	Tal	I	Se, Sa	42	1.13	1.92	3.05
23. Rubiaceae	43. *Anthocephalus chinensis* (Lamk.)	Kadom	I	Se, Sa	72	1.94	1.92	3.84
24. Rutaceae	44. *Zanthoxylum rhetsa* (Roxb.) DC.	Bajna	I	Se, Sa	87	3.77	3.85	7.62
	45. *Aegle marmelos* (Linn.) Correa.	Bel	I	Se, Sa	53			
25. Santalaceae	46. *Santalum album* Linn.	Chondon	I	Se, Sa	19	0.51	1.92	2.43
26. Sapotaceae	47. *Minosops elengi* Linn.	Bakul	I	Se, Sa	39	1.05	1.92	2.97
27. Sterculiaceae	48. *Sterculia villosa* Roxb.	Udol	I	Se, Sa	63	1.7	1.92	3.62
28. Thymeleaceae	49. *Aquilaria agallocha* Lamk.	Agor	I	Se, Sa	40	1.08	1.92	3.0
29. Verbenaceae	50. *Gmelina arborea* (Roxb.) DC.	Gamar	E	Se, Sa	63	5.01	3.85	8.86
	51. *Tectona grandis* L.f.	Teak	E	Coppice	123			
30. Urticaceae	52. *Streblus asper* Lour.	Shewra	I	Se, Sa	42	1.13	1.92	3.05
Unidentified	53. Unidentified-1		E	Se, Sa	39			
	54. Unidentified-2		I	Se, Sa	39			
	55. Unidentified-3		I	Se, Sa	28			

Notes: *I/E, I is Indigenous and E is Exotics; Se is Seedling and Sa is Sapling; ** Unidentified species are not included.

Table 2. Status of regeneration of species at different habitats in KNP and TGEP, Bangladesh

Species	Species location				
	Fallow land N=16(29.09)	Forest N=43(78.18)	Homestead[a] N=7(12.73)	Roadside N=23(41.82)	Others[b] N=7(12.73)
Indigenous, n=40 (100)	7 (17.5)	36 (90)	4(10)	11 (27.5)	5 (12.5)
Exotic, n=15 (100)	9 (60)	7 (46.67)	3(20)	12 (80)	2 (13.33)

Notes: Values in the parenthesis indicate the percentage and N (summation of n) indicates the total number of species; [a]Homestead indicates surrounding forest dwellers house; [b]Others indicates canals, streams and tea gardens, etc.

Table 3. Density (D), Frequency (F), Abundance (A), Relative density (RD) Relative Frequency (RF), Relative Abundance (RA), Importance value index (IVI) of exotic regenerating species in KNP and TGEP, Bangladesh

Scientific name	Density	RD (%)	Frequency (%)	RF (%)	Abundance	RA (%)	IVI
Acacia auriculiformis Willd.	0.28	5.23	18	5.49	1.53	6.37	17.09
Albizia lebbeck (Linn.) Benth.	0.34	6.47	20	6.1	1.7	7.09	19.66
Albizia procera Benth.	0.43	8.09	26.5	8.08	1.6	6.69	22.86
Cassia fistula Linn.	0.25	4.66	17.5	5.34	1.4	5.84	15.84
Senna siamea Lam.	0.39	7.33	20.5	6.25	1.88	7.83	21.41
Dalbergia sissoo Roxb.	0.4	7.52	25	7.62	1.58	6.59	21.73
Eucalyptus camaldulensis Dehn.	0.28	5.23	18.5	5.64	1.49	6.2	17.07
Eucalyptus grandis Hill & ex Maiden.	0.22	4.19	14.5	4.42	1.52	6.33	14.94
Gmelina arborea (Roxb.) DC.	0.32	5.99	22.5	6.86	1.4	5.84	18.69
Lagerstroemia speciosa (Linn.) Pers.	0.42	7.99	26	7.93	1.62	6.74	22.66
Mesua nagassarium (Burn. f.) Kost	0.29	5.52	18	5.49	1.61	6.72	17.73
Swietenia mahagoni (Linn.) Jacq.	0.42	7.9	27	8.23	1.54	6.41	22.54
Tectona grandis L.f.	0.62	11.7	34.5	10.5	1.78	7.44	29.66
Xylia dolabriformis Benth. (K. kerrii)	0.45	8.47	28.5	8.69	1.56	6.51	23.67
Unidentified- 1	0.2	3.71	11	3.35	1.77	7.39	14.46

Table 4. Density (D), Frequency (F), Abundance (A), Relative density (RD), Relative Frequency (RF), Relative Abundance (RA), Importance value index (IVI) of indigenous regenerating species in KNP and TGEP, Bangladesh

Scientific name	Density	RD (%)	Frequency (%)	RF (%)	Abundance	RA (%)	IVI
Aegle marmelos (Linn.) Correa.	0.27	1.92	17	2.09	1.56	2.27	6.27
Alstonia scholaris R.Br.	0.32	2.31	23	2.83	1.39	2.02	7.16
Anthocephalus chinensis (Lamk.) Rich ex.Walp.	0.36	2.6	19	2.34	1.89	2.76	7.69
Aphanamixis polystachya (Wall.) R. N. Park.	0.51	3.69	30	3.69	1.7	2.47	9.85
Aquilaria agallocha Lamk.	0.2	1.45	8	0.98	2.5	3.64	6.07
Artocarpus chaplasha Roxb.	0.58	4.16	32	3.93	1.8	2.61	10.7
Artocarpus heterophyllus Lamk.	0.28	1.99	16.5	2.03	1.67	2.42	6.44
Artocarpus lacucha Buch-Ham.	0.22	1.55	14	1.72	1.54	2.23	5.51
Azadirachta indica A. Juss.	0.42	3.04	26.5	3.26	1.58	2.31	8.6
Baccaurea ramiflora Lour.	0.47	3.4	27	3.32	1.74	2.53	9.25
Bauhinia acuminata Linn.	0.27	1.95	18.5	2.27	1.46	2.12	6.35
Bixa orellana Linn.	0.22	1.55	15.5	1.91	1.39	2.02	5.48
Bombax ceiba Linn.	0.44	3.18	21	2.58	2.1	3.05	8.81
Borassus flabellifer Linn.	0.21	1.52	14.5	1.78	1.45	2.11	5.41
Casuarina equisetifolia Linn.	0.15	1.05	7	0.86	2.07	3.01	4.92
Chickrassia tabularis Juss.	0.59	4.23	32.5	4	1.8	2.62	10.8
Dipterocarpus turbinatus Gaertn.	0.45	3.22	16.5	2.03	2.7	3.92	9.17
Ficus benghalensis Linn.var.krishnae (C.DC.) Corner	0.34	2.42	24.5	3.01	1.37	1.99	7.42
Ficus recemosa Linn.	0.47	3.36	26	3.2	1.79	2.6	9.16
Ficus roxburghii Wall	0.5	3.58	27	3.32	1.83	2.67	9.56
Hydnocarpus kurzii (King) Warb.	0.38	2.71	18	2.21	2.08	3.03	7.95
Litsea monopetala (Roxb.) Pers.	0.32	2.28	15.5	1.91	2.03	2.96	7.14
Mangifera indica Linn.	0.26	1.84	19.5	2.4	1.31	1.9	6.14

Continued Table 4

Scientific name	Density	RD (%)	Frequency (%)	RF (%)	Abundance	RA (%)	IVI
Melia sempervirens (Linn.) All.	0.37	2.64	19.5	2.4	1.87	2.72	7.76
Michelia champaca Linn.	0.53	3.83	30.5	3.75	1.74	2.53	10.1
Minosops elengi Linn.	0.2	1.41	10	1.23	1.95	2.84	5.48
Phyllanthus emblica Linn.	0.37	2.64	29.5	3.63	1.24	1.8	8.06
Santalum album Linn.	0.1	0.69	6.5	0.8	1.46	2.13	3.61
Sterculia villosa Roxb.	0.32	2.28	20	2.46	1.58	2.29	7.03
Streblus asper Lour.	0.21	1.52	15	1.84	1.4	2.04	5.4
Syzygium grande (Roxb.) DC.	0.51	3.65	31.5	3.87	1.6	2.33	9.85
Tamarindus indica Linn.	0.35	2.49	23	2.83	1.5	2.18	7.5
Terminalia arjuna W & A.	0.57	4.08	32	3.93	1.77	2.57	10.6
Terminalia bellirica (Gaertn) Roxb.	0.31	2.24	18	2.21	1.72	2.51	6.96
Terminalia chebula (Gaerth.)Retz.	0.33	2.39	23.5	2.89	1.4	2.04	7.32
Toona ciliata J.Roem.	0.46	3.29	26	3.2	1.75	2.55	9.03
Trewia polycarpa Benth.	0.32	2.31	15.5	1.91	2.06	3	7.22
Zanthoxylum rhetsa (Roxb.) DC.	0.44	3.14	20	2.46	2.18	3.16	8.77
Unidentified- 2	0.2	1.41	13.5	1.66	1.44	2.1	5.17
Unidentified- 3	0.14	1.01	10.5	1.29	1.33	1.94	4.24

Biological diversity indices of regenerating species

According to Khumbongmayun et al. (2005), the species richness is one of the foremost criteria in recognizing the importance of an area for conservation of biodiversity. Rahman et al. (2000), believed that higher the value of diversity, greater would be the stability of community. Different biological diversity indices for natural regeneration of indigenous and exotic species in KNP and TGEP of Bangladesh are explored in Table 5. Diversity indices such as Species diversity index (SDI), Species richness index (R), Shannon-Winner diversity index (H), Species evenness index (E), Simpson index (D) were analyzed to get a clear picture about the regeneration status of both indigenous and exotic species. Shannon-Winner diversity index (H), Shannon's maximum diversity index (H_{max}), Species richness index (R) and dominance of Simpson index (D') value were found to be highest for indigenous species where Species evenness index (E) and Simpson index (D) value were highest for exotic species. However, the value of Shannon's equitability index (E_H) and Species diversity index (SDI) was same for both species. The results indicated that the regeneration status of the two study areas were very adequate and specify, which is converted into a diversity rich forest through protection and scientific management of regenerating species as well as whole forest ecosystem.

Table 5. Different biological diversity indices for regeneration status in KNP and TGEP, Bangladesh

Species	Diversity index							
	H	Hmax	EH	SDI	R	E	D	D'
Indigenous	3.62	3.69	0.98	0.01	4.92	2.26	0.03	0.97
Exotic	2.66	2.71	0.98	0.01	2.01	2.27	0.07	0.93

Notes: H is Shannon-Winner diversity index, H_{max} is Shannon's maximum diversity index, E_H is Shannon's equitability index, SDI is Species diversity index, R is Species richness index, E is Species evenness index, D is Simpson index, D' is Dominance of Simpson index.

Discussion

Information on the species composition of a forest is essential for its wise management in terms of economic value, regeneration potential (Wyatt-Smith 1987) and ultimately may be leading to conservation of biological diversity (Verma et al. 1999). Natural regeneration potential is an important indicator for any forest ecosystems. Nevertheless, very scanty or almost no information is available on the composition, distribution and status of natural regeneration species of the study forests. In two biodiversity conservation areas (Khadimnagar National Park (KNP) and Tilagaor Eco-Park (TGEP)), a detailed survey of regeneration species of trees was undertaken to provide complete information on the species composition, distribution and quantitative structure of species. However, in the present study, the number of species recorded in KNP and TGEP was much higher than that recorded in other natural and plantation forests of Bangladesh (Table 6).

Table 6. Summary of regeneration plant inventory in KNP and TGEP, Bangladesh

Variable	Indigenous	Exotic
Number of individuals	2580	1238
Number of species	40	15
Number of family	20	11
Number of genera	28	15
Disturbance scores*	9	6

Notes: *Disturbace score includes- pest and disease attack, human and wild animals interference, loss of habitat and shelter for animals, drought, poor drainage, low moisture, associated species, unsustainable collection of fuel wood and medicinal plants, over-exploitation of species, etc.

Hossain (1994) recorded 52 tree species of 32 families in the Sitapahar natural forest of Chittagong Hill Tracts (South) forest division of Bangladesh. Ahmed and Bhuyian (1994) found 42

known and few unknown regenerating species in the natural forest of Cox's Bazar Forest Division, Bangladesh. Hossain et al. (2004) in a comparative study of natural regeneration of natural forest and enrichment plantation in Chittagong (south) forest division, Bangladesh recorded 64 species from natural forest and 40 species from enrichment plantations; Alamgir and Al-Amin (2007) documented 39 species under 18 families in a proposed biodiversity conservation area (Bamerchara and Danerchara) in Chittagong, Bangladesh.

The various studies showed that open canopy might be in favor of seed germination and seedling establishment through increased solar radiation on the forest floor (Khan et al. 1987; Kadavul et al. 1999). Regeneration is a critical phase of forest management, because it maintains the desired species composition and stocking after disturbances (Duchok et al. 2005). In Bangladesh, there are approximately 5000 species of angiosperms (Nath et al. 1998) and the regeneration density or regeneration capacity of species is low in a high-competition environment, i.e. in grass and ferns.

The Importance Value Index (IVI) of any species indicates the dominance of species in a mixed population (Sharma 1979). From the present study, it was found that *Tectona grandis*, *Xylia dolabriformis*, *Albizia procera*, *Lagerstroemia speciosa*, *Swietenia mahagoni*, *Dalbergia sissoo* Roxb., and *Cassia siamea* Lam., were dominated in exotic species. In indigenous species, the dominated species were estimated for *Chickrassia tabularis*, *Artocarpus chaplasha*, *Terminalia arjuna*, *Michelia champaca*, *Ficus roxburghii*, *Baccaurea ramiflora*, and *Syzygium grande*, so on as well as these species are important from the both biodiversity conservation and commercial point of view.

On the family level, Moraceae and Meliaceae were the dominant families for both exotic and indigenous species. Probably, the dominance of these two families is due to the excellent dispersal capacities of their seeds, pollen grains, etc. by wind, water, birds, mammals, bats, and humans. The natural growing of fruit tree species like *Aegle marmelos, Artocarpus chaplasha*, *Artocarpus heterophyllus*, *Artocarpus lacucha*, *Azadirachta indica*, *Bixa orellana*, *Bombax ceiba*, *Borassus flabellifer*, *Ficus roxburghii*, *Ficus bengalensis*, *Ficus racemosa*, *Mangifera indica*, *Terminalia chebula*, *Terminalia belerica*, *Phyllanthus emblica*, *Tamarindus indica* and *Syzygium grande* etc. species provide food and natural habitat to the animal diversity.

Forest Department's plantations strategy was considered as one of the major causes for forest and biodiversity degradation. The targeted plantation aimed at producing high valued timber trees. In addition, exotic trees or mono species were planted in these areas. Therefore, no biodiversity conservation strategy was considered. Bamboo, rattan, and agar are also planted in an extensive area. The plantation practices, including clearing and subsequent weeding of the proposed plantation areas have contributed to biodiversity loss and habitat loss for the wildlife. Major threat for natural regeneration in both sites is indiscriminate collection of fuelwood by the surrounding people at sapling period of tree species leaves. Another severe threat to the newly regenerated tree species is grazing and trampling by the cattle of the adjacent people. Therefore, a core area and a buffer zone would need to be demarcated for forest resource management and sufficient care is needed to implement various developmental activities related to forest management.

Public awareness has to be developed and special priority ought to give to conserve and protect the regeneration of tree species, which are facing tremendous pressure from increasing population and urbanization. So, effective forest policies are needed for sustainable management of forest ecosystem which is not only to manage and conserve the existing the natural resources, ecosystems but also for the restoration of natural ecosystem through cooperation and support of local dwellers. A project named Integrated Protected Area Co-management (IPAC) is running since 2009 in KNP collaborated with the local people that will be helpful to improvements in forest and resource conservation and buffer zone with some specific forest management objectives. These two biodiversity conservation areas are rich in regenerating species that could result in the establishment of a diverse natural forest if the seedlings or saplings of the regenerating species are conserved according to proper management strategy.

Conclusions

The findings of present study provide a complete view of regeneration status in the study areas and possess a rich regeneration species composition, status and diversity. Data from five types of habitats proved that they are also profound in their surrounding locations. The present study suggests that disturbances such as extraction of seedling/saplings for fuelwood, grazing, disturbance of seed dispersal, etc. has brought a decline in plant communities. The present study in and around two-biodiversity conservation areas is a small sample for exploring the actual thing for natural regeneration composition, status and diversity. Further study is highly recommended to reexamine the present findings. The study finally concludes that a proper protection from human interferences and scientific management of natural regeneration of the study areas may lead a biodiversity rich site in the country.

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